Diversity of Life and Cell Structure

Chapter 4

Biol406, Week 3, Lecture section

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The Cell: The Fundamental Units of Life

Cell Theory states:

- All living organisms are made of cells
- The cell is the simplest collection of matter that can live
- Cell structure is correlated to cellular function
- All cells descend from other cells

Two Types of cells: prokaryotic or eukaryotic

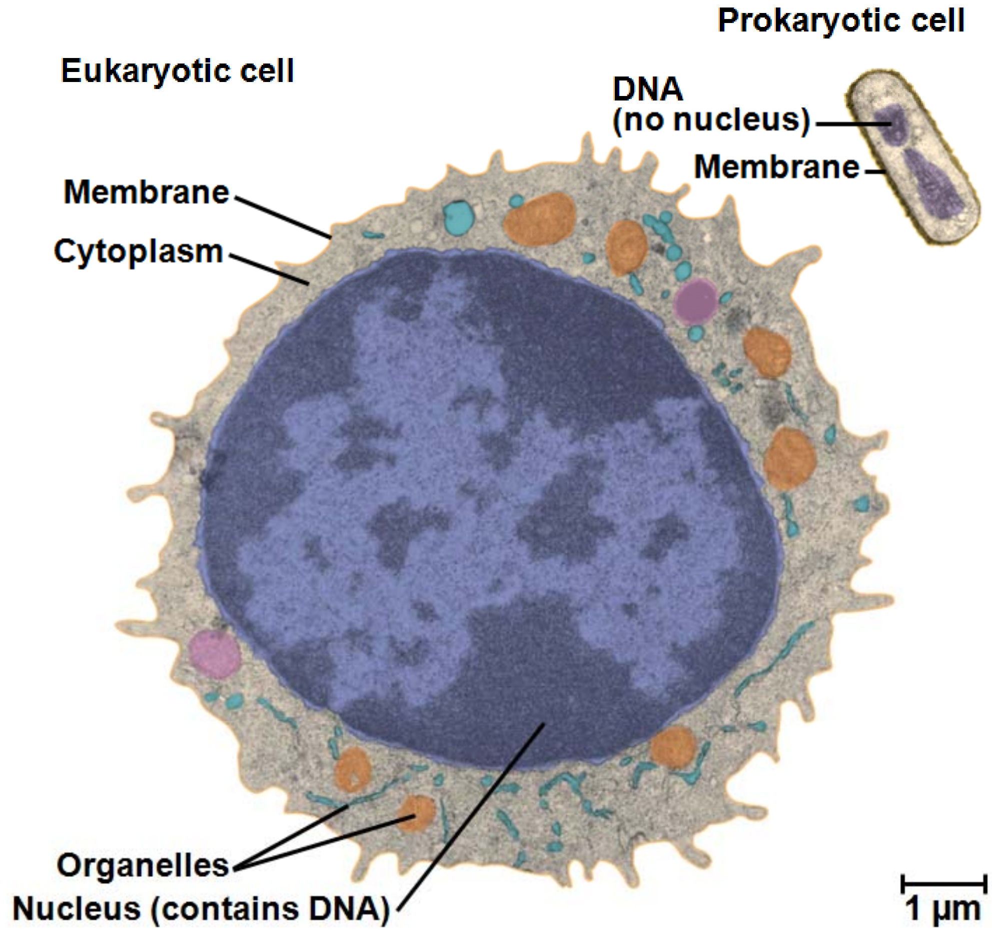
A **eukaryotic cell** has membrane-enclosed organelles, the largest of which is usually the nucleus

By comparison, a **prokaryotic cell** is simpler and usually smaller, and does not contain a nucleus or other membrane-enclosed organelles

Bacteria and Archaea are prokaryotic

Plants, animals, fungi, and protists are eukaryotic

Domains:
Bacteria and Archaea



Domain:
Eukarya

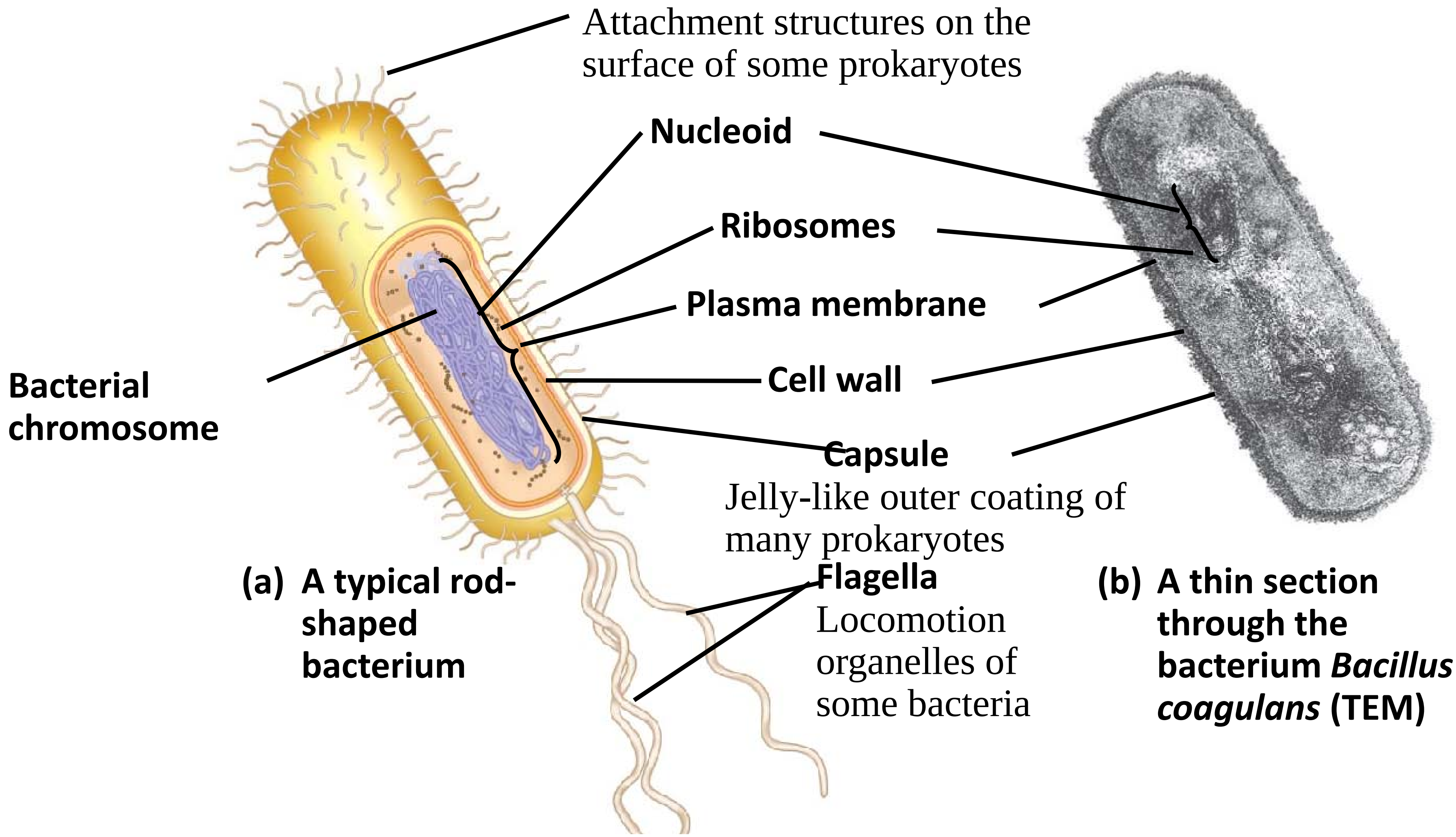
Comparing Prokaryotic and Eukaryotic Cells

All cells have several basic features in common:

- Plasma membrane surround the cells
- Semifluid substance called **cytosol (inside)**
- Chromosomes (carry genes in the form of DNA)
  - Prokaryotic cells: Lack a nucleus
  - Eukaryotic cells: Have a nucleus (a membrane encloses the DNA)
- Ribosomes (make proteins)

- **Prokaryotic cells** are characterized by having
  - No nucleus
  - DNA is in an unbound region called the **nucleoid**
  - No membrane-bound organelles
  - The interior of a prokaryotic cell is called the **cytosol** (soup-like fluid without organelles)
  - They have ribosomes and a plasma membrane.
  - Cell wall covering their plasma membrane:
    - Made of peptidoglycan in bacteria
    - Without peptidoglycan in archaea

A prokaryotic Cell:



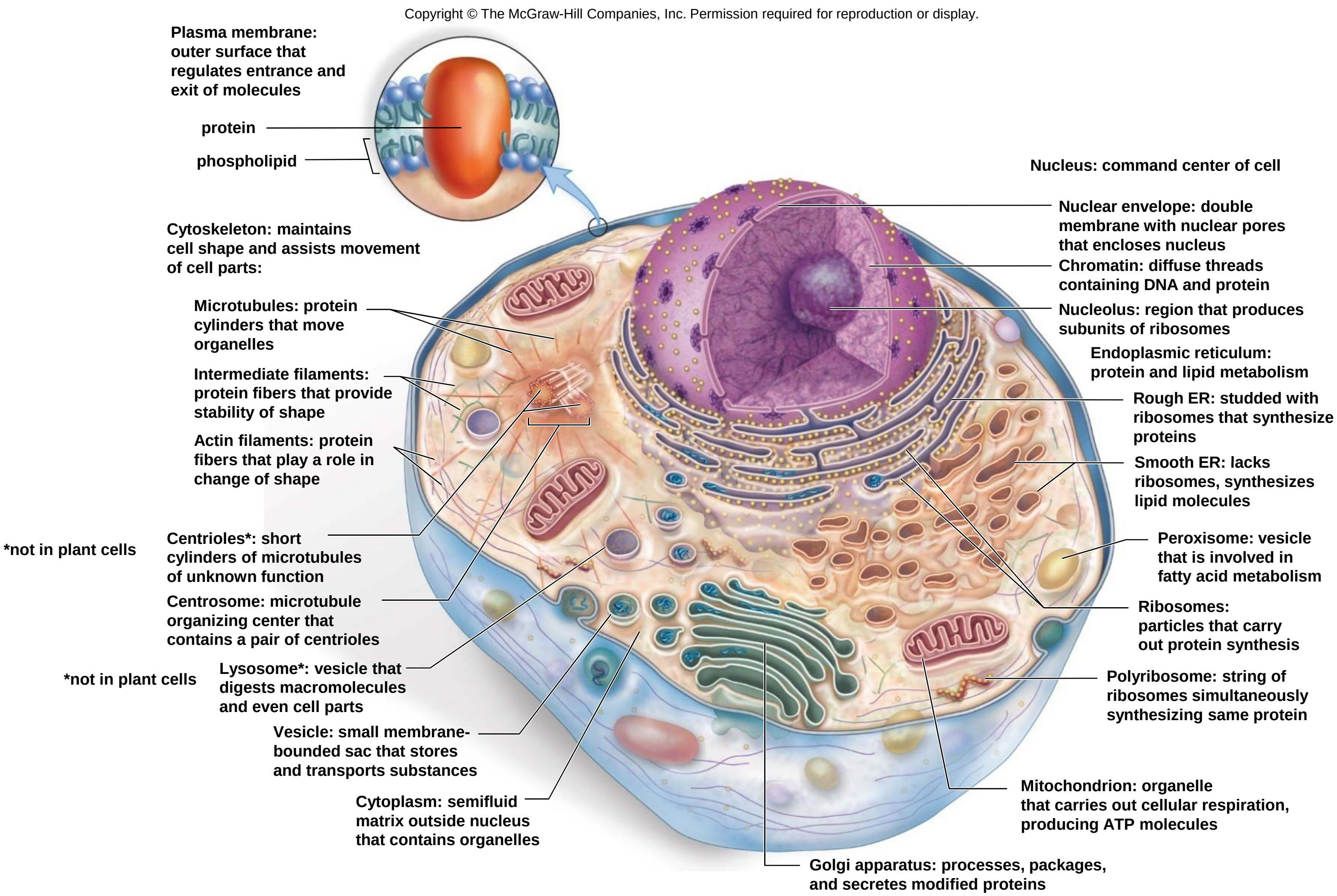
(a) A typical rod-shaped bacterium

(b) A thin section through the bacterium *Bacillus coagulans* (TEM)

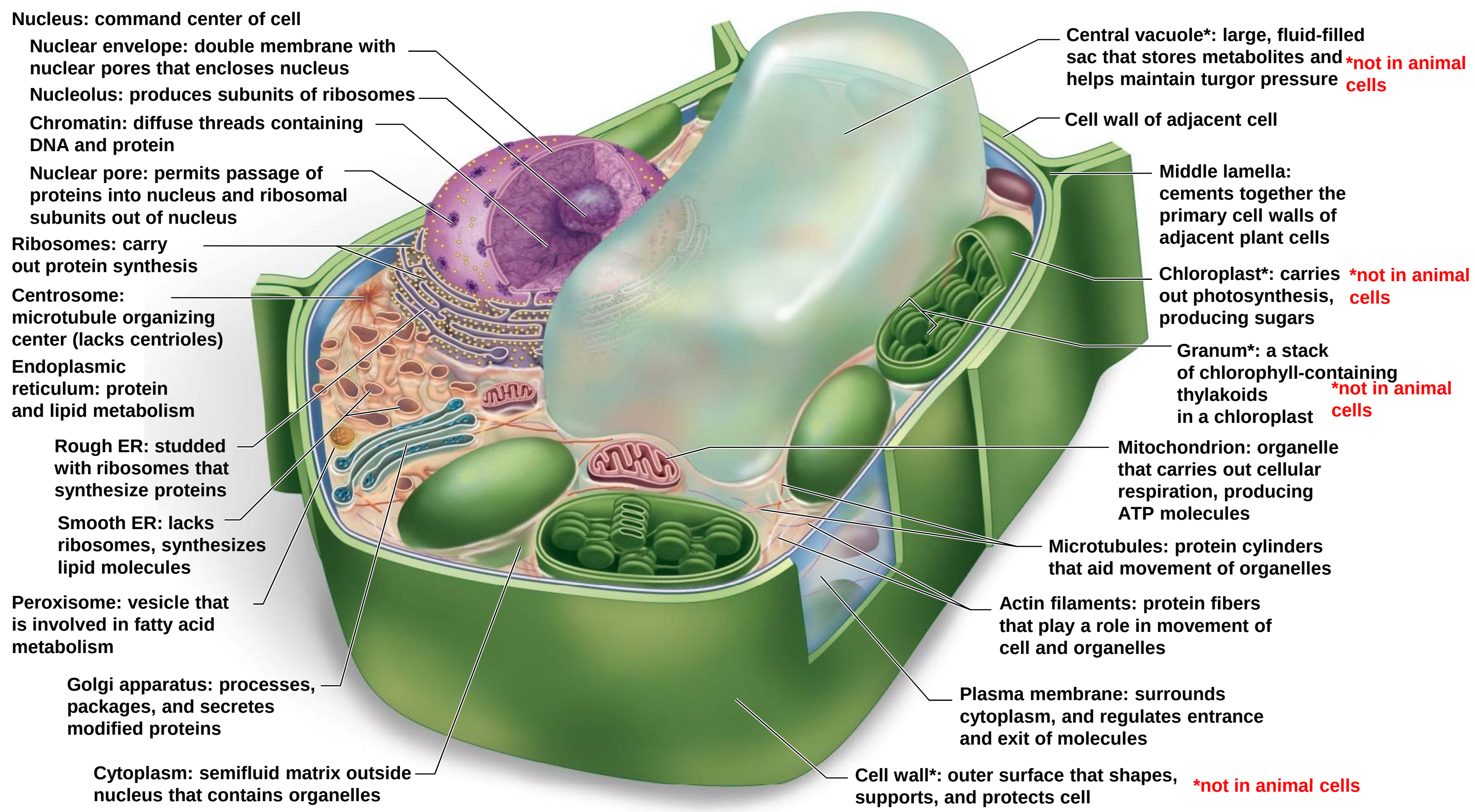
Nucleoid: Region where the cell’s DNA is located (not enclosed by a membrane)
Ribosomes: Complexes that synthesize proteins
Plasma membrane: Membrane enclosing the cytoplasm
Cell wall: Rigid structure outside the plasma membrane

- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a double-membranous nuclear envelope
  - Membrane-bound organelles
  - Cytoplasm in the region between the plasma membrane and nucleus (cytoplasm=cytosol+ small organelles)
- Eukaryotic cells are generally much larger than prokaryotic cells
- Plant and animal cells have most of the same organelles (with some exceptions)

Animal Cell Anatomy



Plant Cell Anatomy

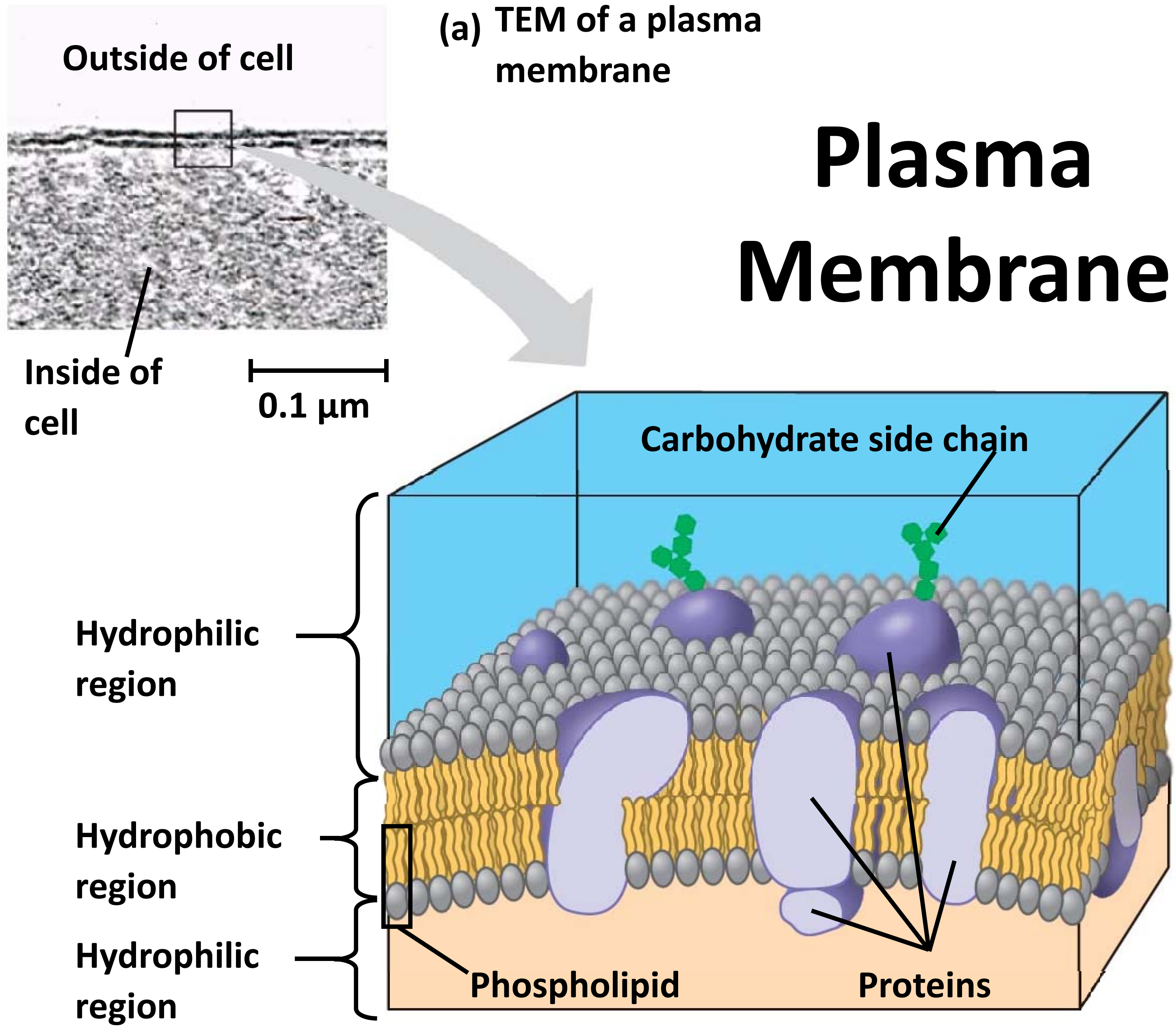


The **plasma membrane is found in all cells**

is a selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the entire cell

The general structure of a biological membrane is a double layer (bilayer) of phospholipids with proteins attached to or embedded in it. Some carbohydrates are also bonded to some of the phospholipids and proteins

Plasma Membrane

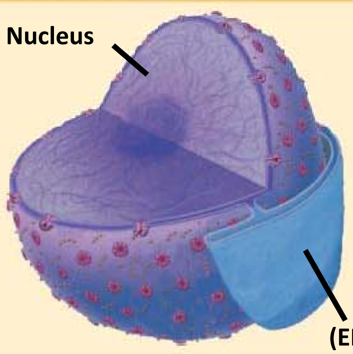


(a) TEM of a plasma membrane

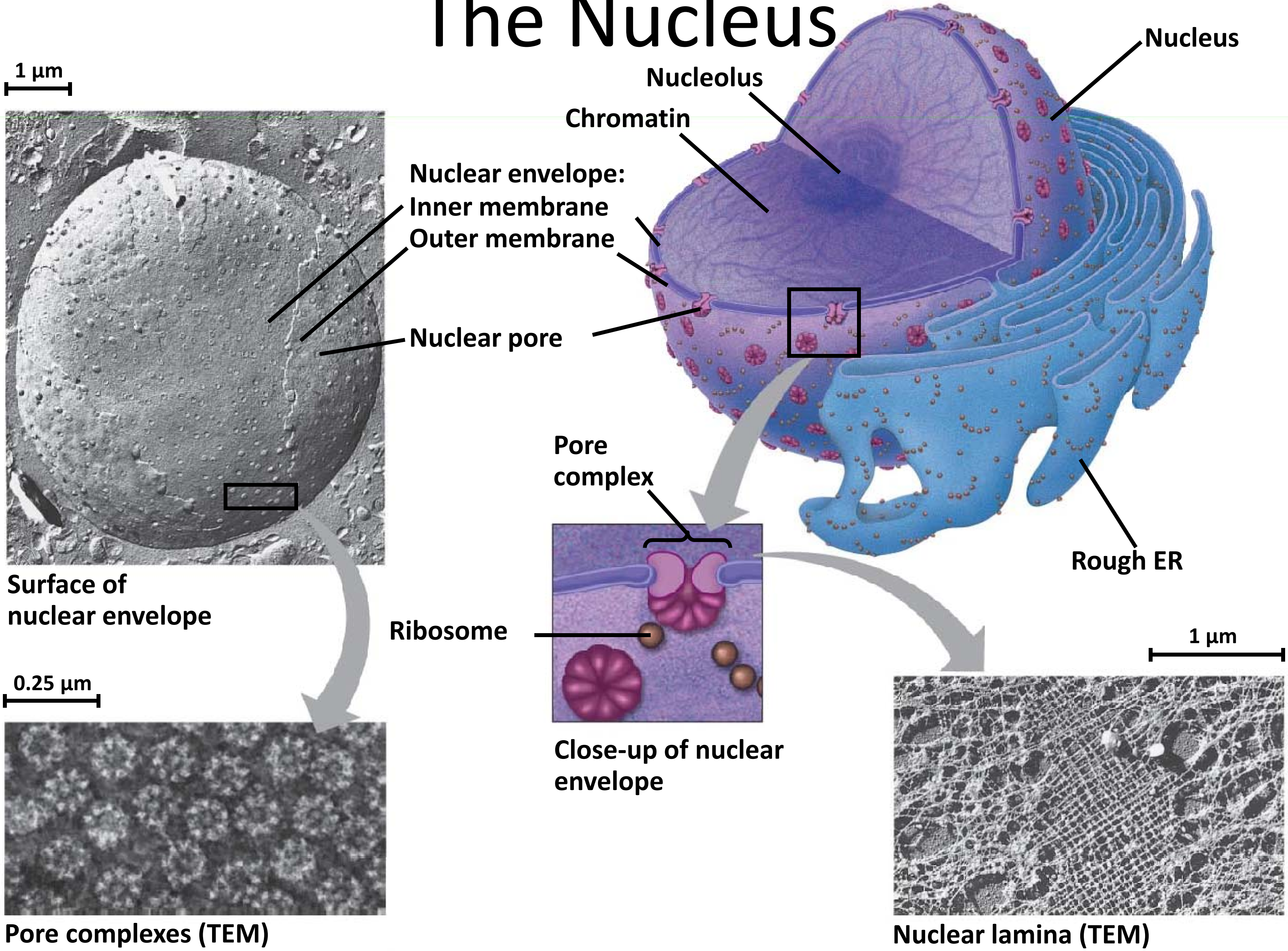
(b) Structure of the plasma membrane

The nucleus and the ribosomes

- The nucleus contains most of the genes (DNA) in the eukaryotic cell (some genes are also located in mitochondria and chloroplasts)
- Ribosomes use the information from the DNA to make proteins (Protein synthesis)

	Cell Component	Structure	Function
Concept 6.3 **The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes**	**Nucleus** 	**Surrounded by nuclear envelope (double membrane) perforated by nuclear pores. The nuclear envelope is continuous with the endoplasmic reticulum (ER).**	**Houses chromosomes, made of chromatin (DNA, the genetic material, and proteins); contains nucleoli, where ribosomal subunits are made. Pores regulate entry and exit os materials.**
	Ribosome 	**Two subunits made of ribo-somal RNA and proteins; can be free in cytosol or bound to ER**	**Protein synthesis**

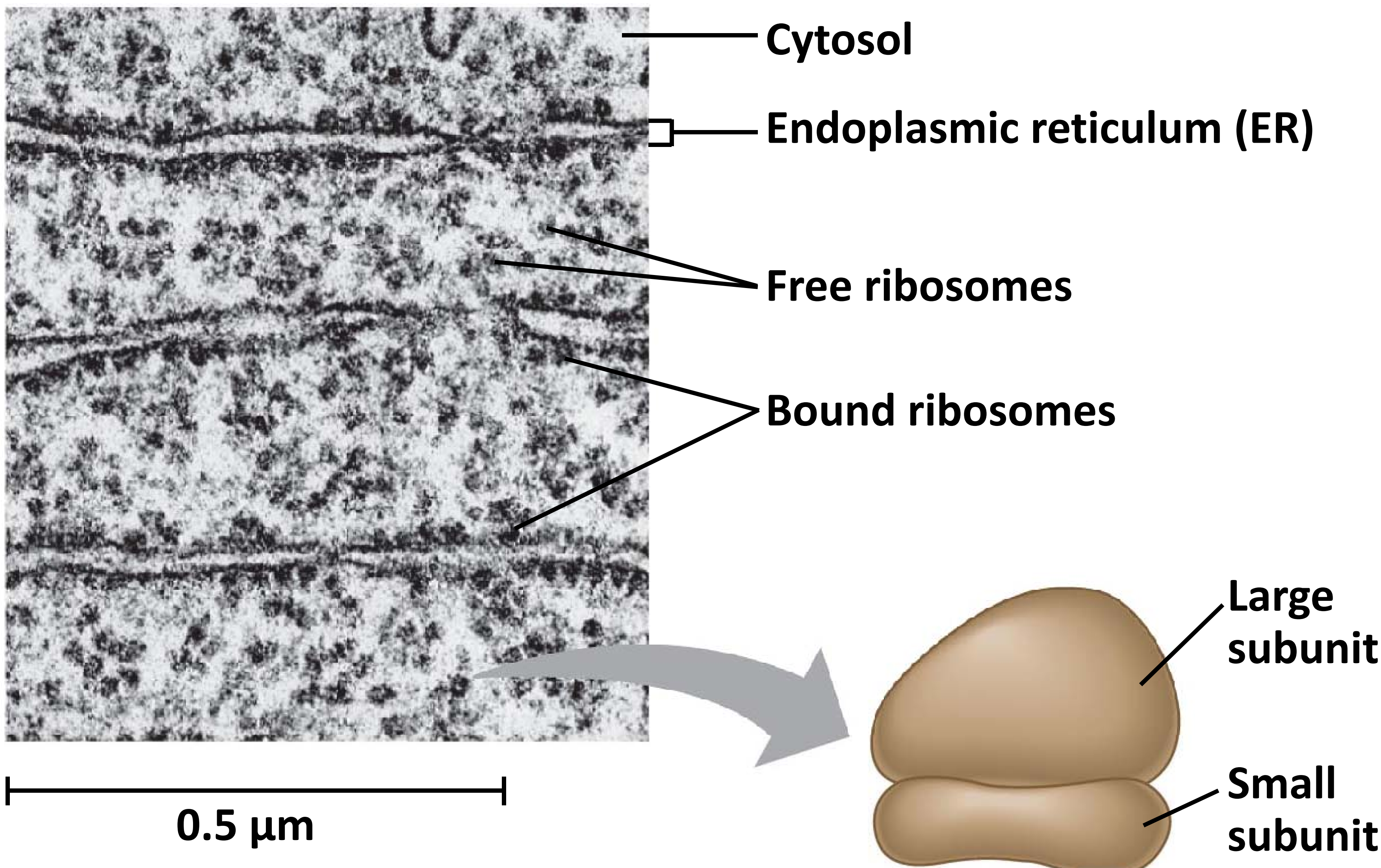
The Nucleus


1 µm
Nucleolus
Nucleus
Chromatin
Nuclear envelope:
Inner membrane
Outer membrane
Nuclear pore
Pore complex
Rough ER
Surface of nuclear envelope
Ribosome
1 µm
0.25 µm
Close-up of nuclear envelope
Pore complexes (TEM)
Nuclear lamina (TEM)

Ribosomes: Protein Factories

- **Ribosomes** are complexes made of ribosomal RNA and protein
- Ribosomes carry out protein synthesis in two locations:
  - In the cytosol (free ribosomes)
  - On the outside of the endoplasmic reticulum (rough endoplasmic reticulum) or the nuclear envelope (bound ribosomes)

Fig. 6-11

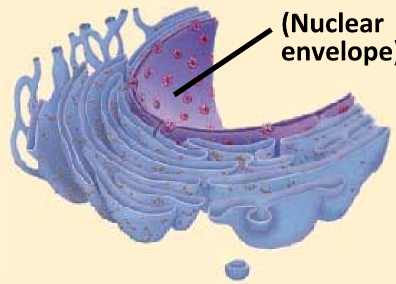
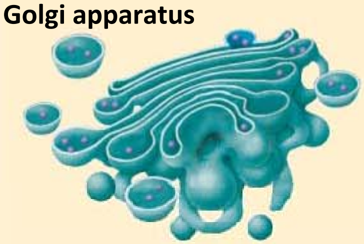


TEM showing ER and ribosomes

Diagram of a ribosome

The endomembrane system

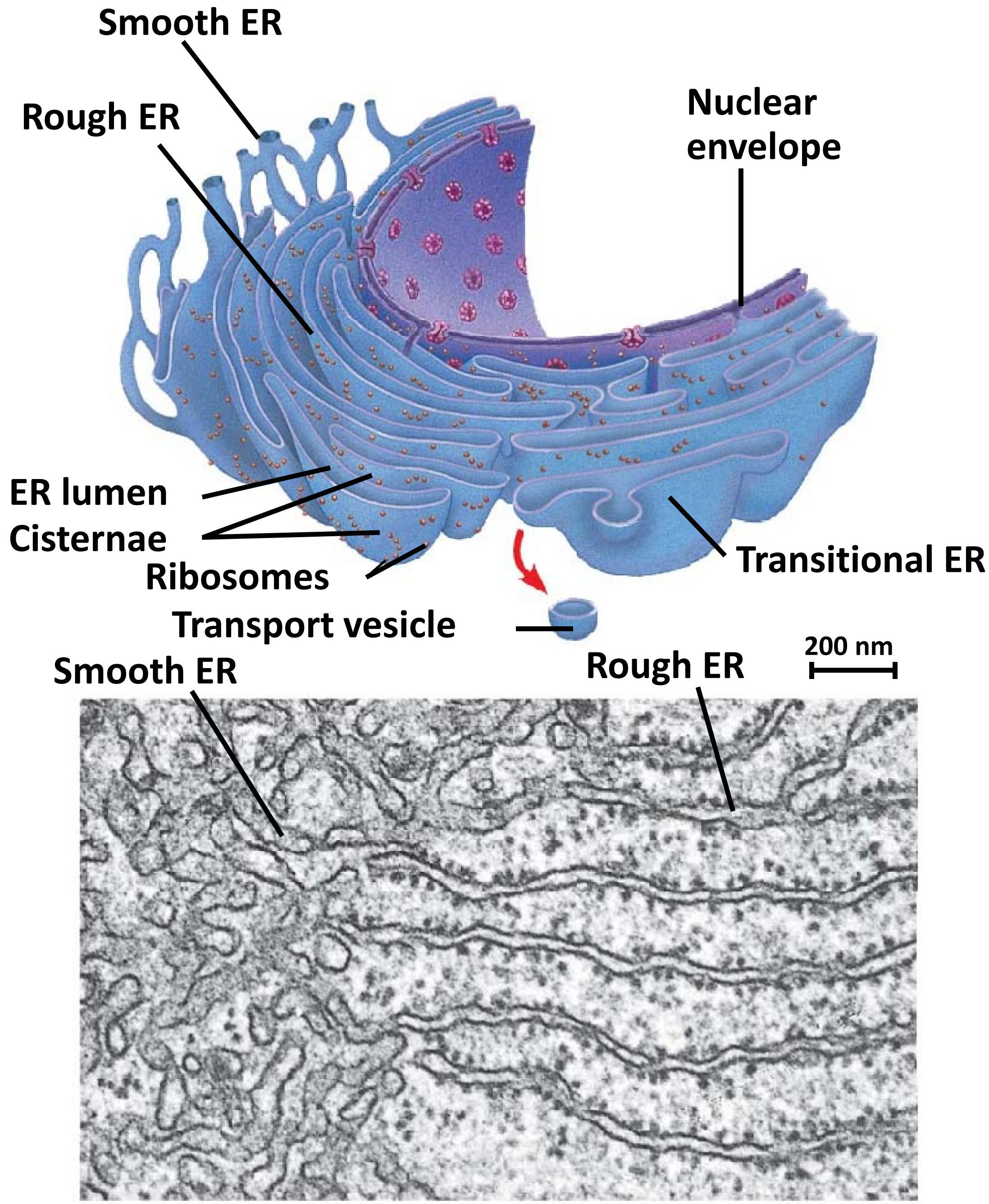
- Regulates protein traffic and perfoms metabolic functions in the cell
- Components of the **endomembrane system**:
  - Nuclear envelope
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes
  - Vacuoles
  - Plasma membrane
- The membranes of this systems are related either through direct physical continuity or by the transfer of membrane segments in the form of vesicles (sacs made of membrane)

	Cell Component	Structure	Function
Concept 6.4 **The endomembrane system regulates protein traffic and performs metabolic functions in the cell**	**Endoplasmic reticulum**  	**Extensive network of membrane-bound tubules and sacs; membrane separates lumen from cytosol; continuous with the nuclear envelope.**	**Smooth ER: synthesis of lipids, metabolism of carbohydrates, Ca^{2+} storage, detoxification of drugs and poisons** **Rough ER: Aids in sythesis of secretory and other proteins from bound ribosomes; adds carbohydrates to glycoproteins; produces new membrane**
	Golgi apparatus 	**Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces)**	**Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles.**
	Lysosome 	**Membranous sac of hydrolytic enzymes (in animal cells)**	**Breakdown of ingested substances cell macromolecules, and damaged organelles for recycling**
	Vacuole 	**Large membrane-bounded vesicle in plants**	**Digestion, storage, waste disposal, water balance, cell growth, and protection**

The Endoplasmic Reticulum: Biosynthetic Factory

- The **endoplasmic reticulum (ER)** accounts for more than half of the total membrane in many eukaryotic cells
- The ER membrane is continuous with the nuclear envelope
- There are two distinct regions of ER:
  - **Smooth ER**, which lacks ribosomes
  - **Rough ER**, with ribosomes studding its surface

Fig. 6-12


Smooth ER
Rough ER
Nuclear envelope
ER lumen
Cisternae
Ribosomes
Transport vesicle
Transitional ER
Smooth ER
Rough ER
200 nm

Functions of the ER

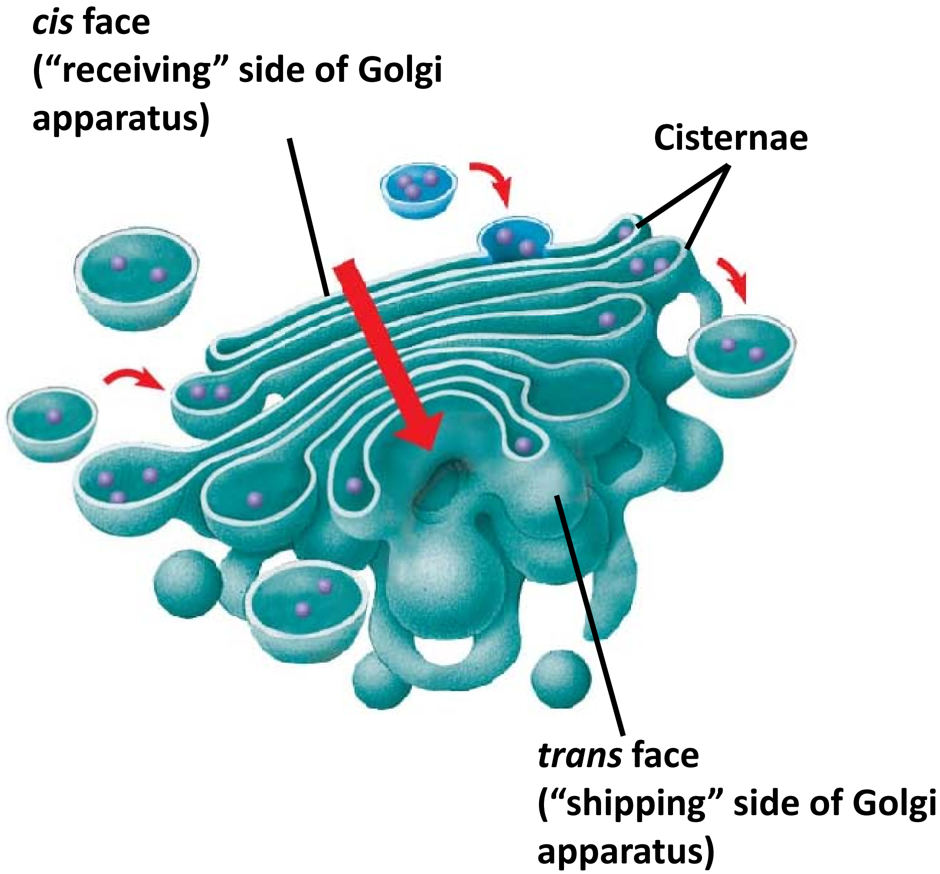
- The smooth ER
  - Synthesizes lipids
  - Gets rid of poisons and toxins
  - Stores calcium

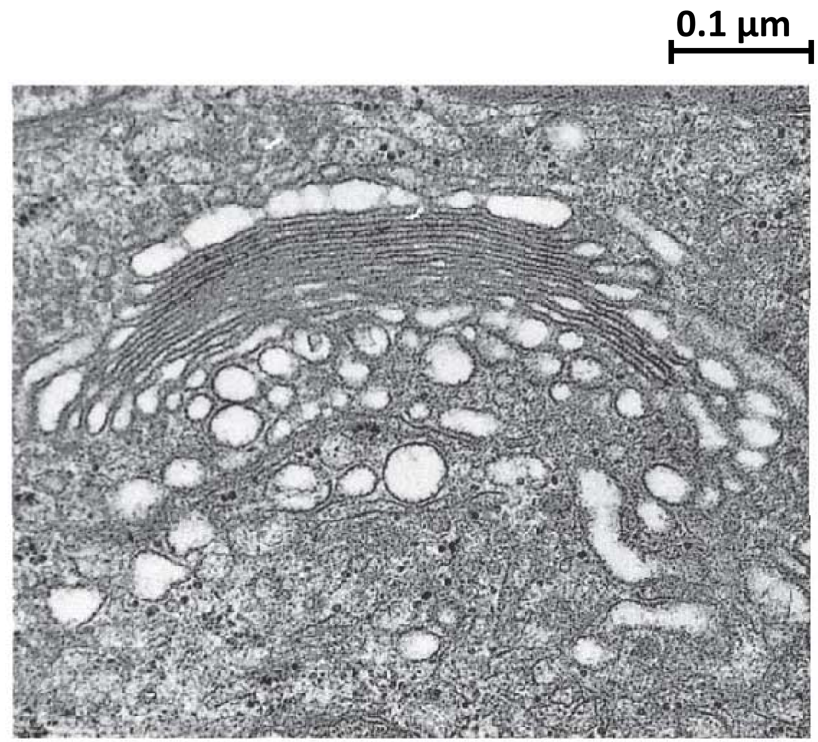
- The rough ER
  - Aids in the synthesis of secretory and other proteins in ribosomes
  - Adds carbohydrates to glycoproteins

The Golgi Apparatus: Shipping and Receiving Center

- The **Golgi apparatus** consists of flattened membranous sacs called cisternae
- Functions of the Golgi apparatus:
  - Modifies products of the ER
  - Manufactures certain macromolecules
  - Sorts and packages materials into transport vesicles

Fig. 6-13



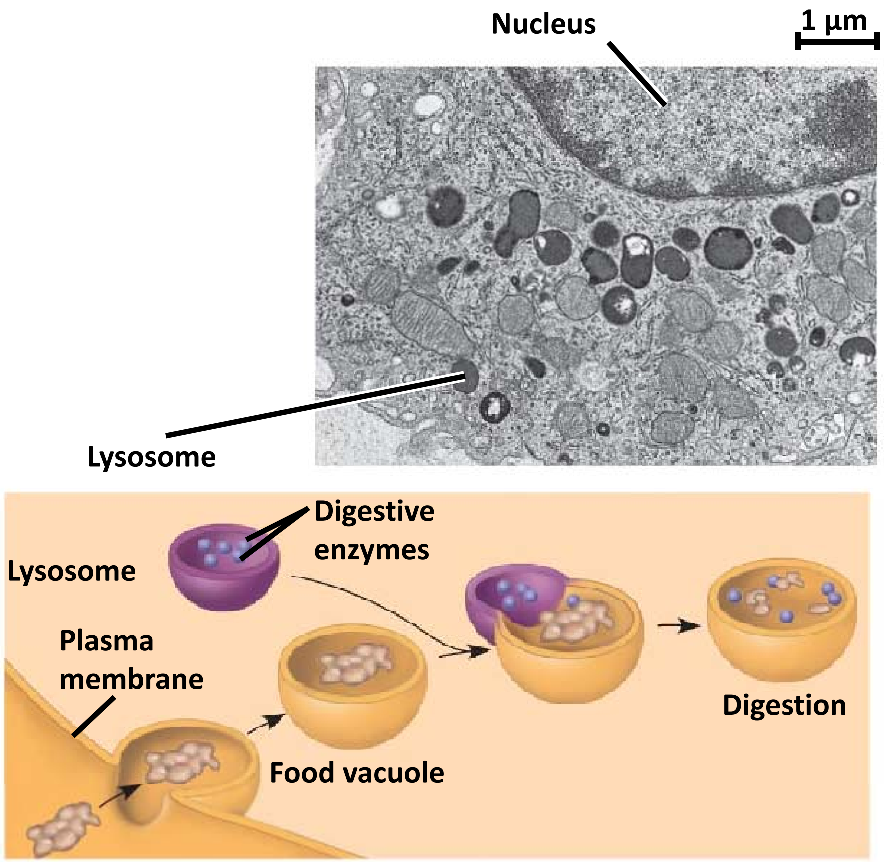


TEM of Golgi apparatus

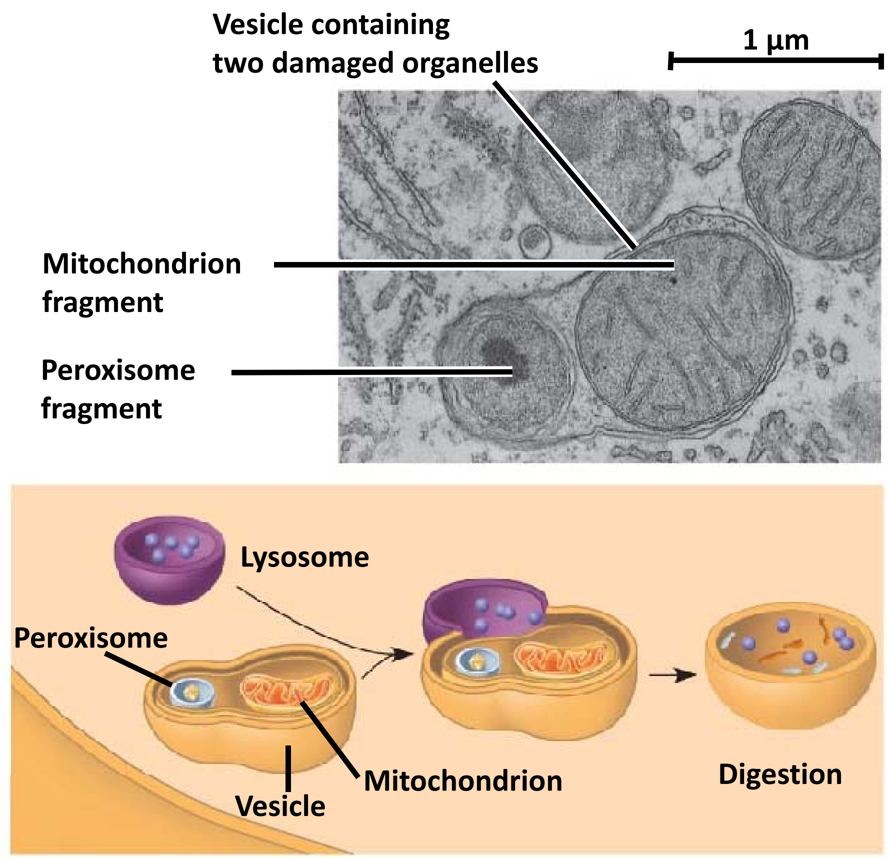
Lysosomes: Digestive Compartments

- A **lysosome** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids
- Some types of cell can engulf another cell by **phagocytosis**; this forms a food vacuole
- A lysosome fuses with the food vacuole and digests the molecules
- Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules, a process called **autophagy**

Fig. 6-14



(a) Phagocytosis

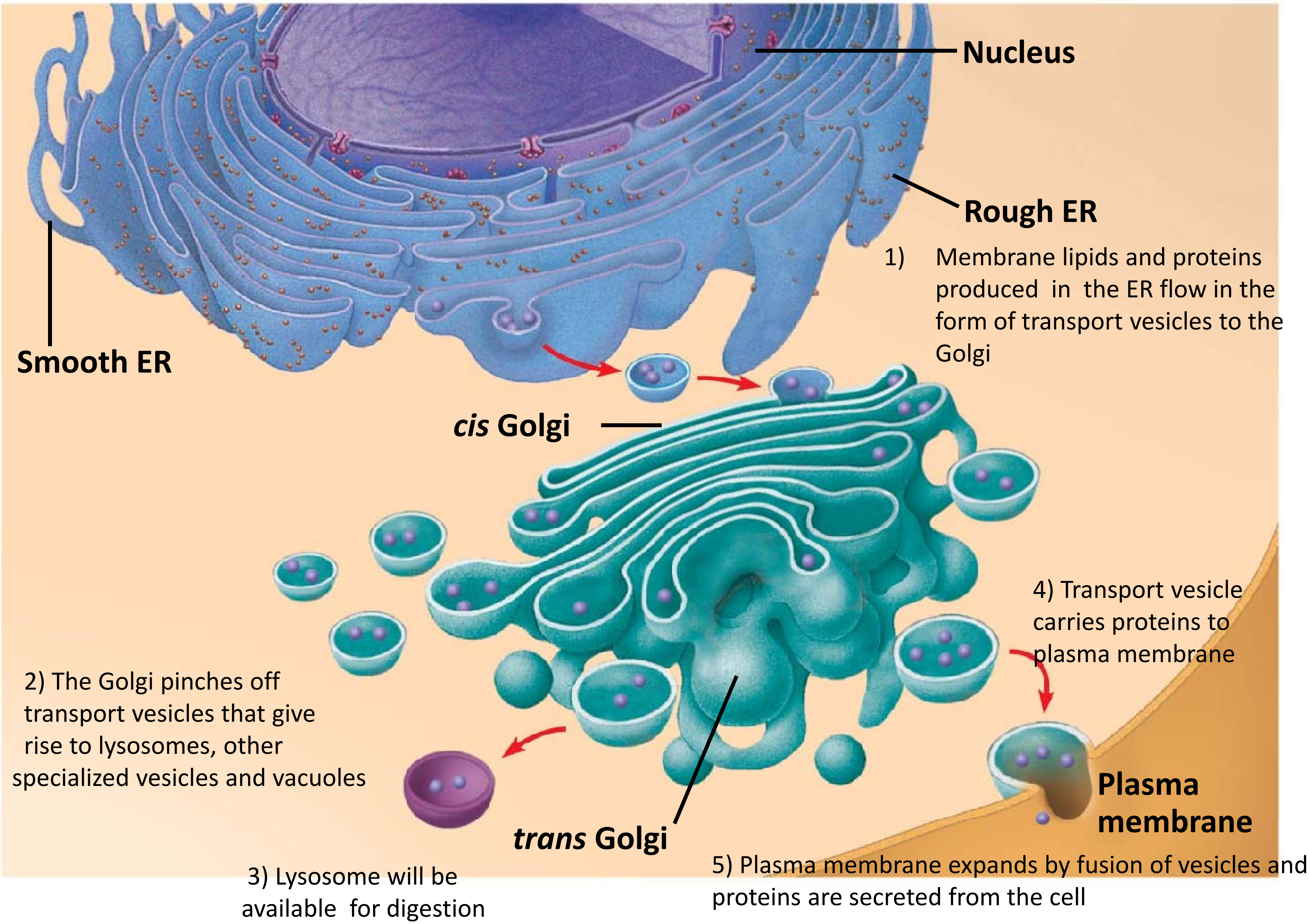


(b) Autophagy

Lysosome digesting food. They hydrolyze materials taken into the cells by food vacuoles
Example: Macrophages ingests bacteria and viruses to destroy them using lysosomes

Lysosome breaking down damaged organelles
Example: Rat liver cell with damaged organelles that have to be eliminated by lysosomes

Fig. 6-16-3

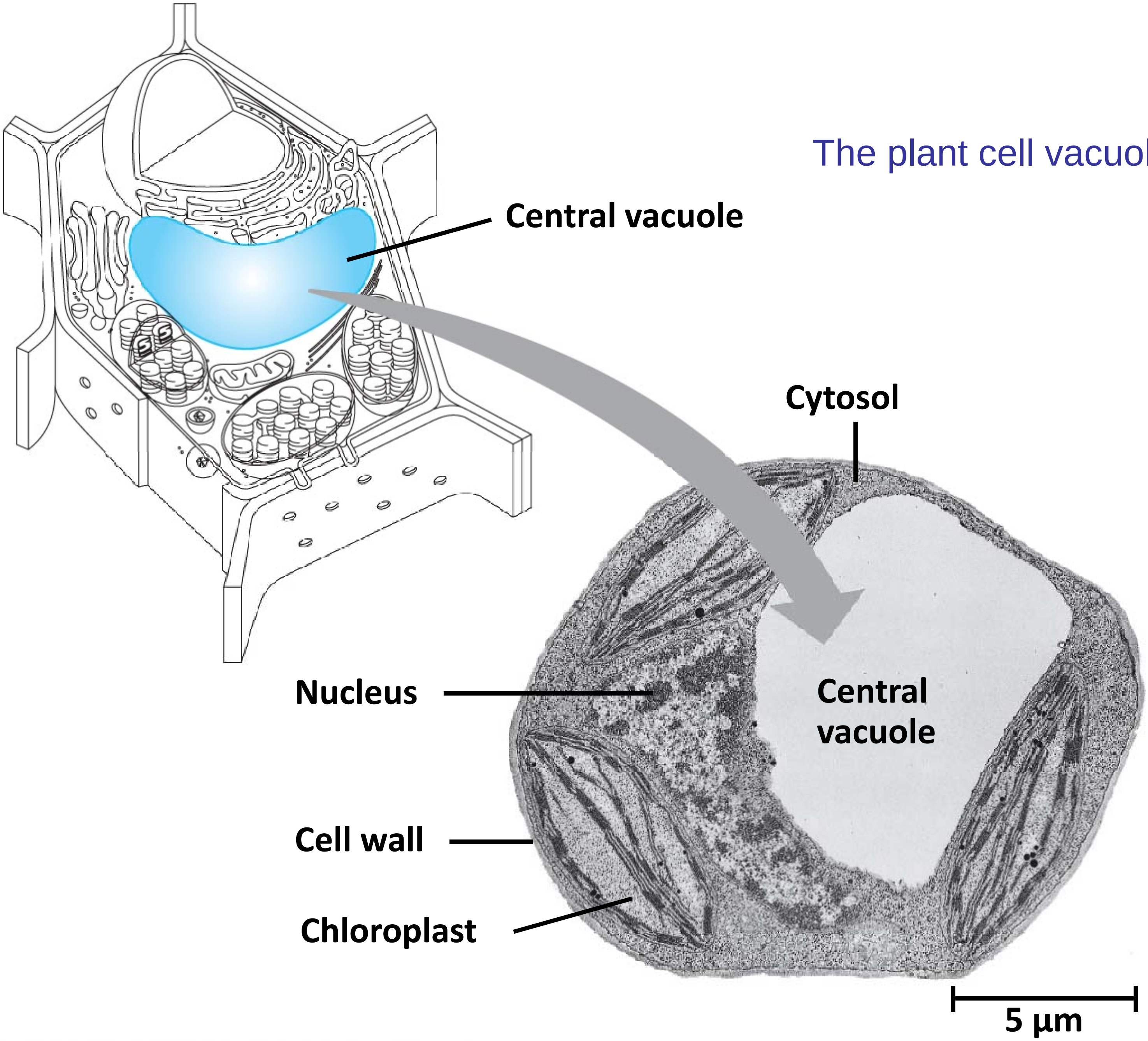

Nucleus
Rough ER
1) Membrane lipids and proteins produced in the ER flow in the form of transport vesicles to the Golgi
Smooth ER
cis Golgi
4) Transport vesicle carries proteins to plasma membrane
2) The Golgi pinches off transport vesicles that give rise to lysosomes, other specialized vesicles and vacuoles
Plasma membrane
trans Golgi
3) Lysosome will be available for digestion
5) Plasma membrane expands by fusion of vesicles and proteins are secreted from the cell

Vacuoles in Plant Cells only

- Membranous sacs that are larger than vesicles
  - Store materials that occur in excess
  - May be very specialized (contractile vacuole, found in many freshwater protists, pump excess water out of cells)
- Plants cells typically have a central vacuole
  - Up to 90% of the volume of some cells
  - Functions in:
    - Storage of water, nutrients, pigments, and waste products
    - Some functions performed by lysosomes in animal cells

Fig. 6-15

The plant cell vacuole

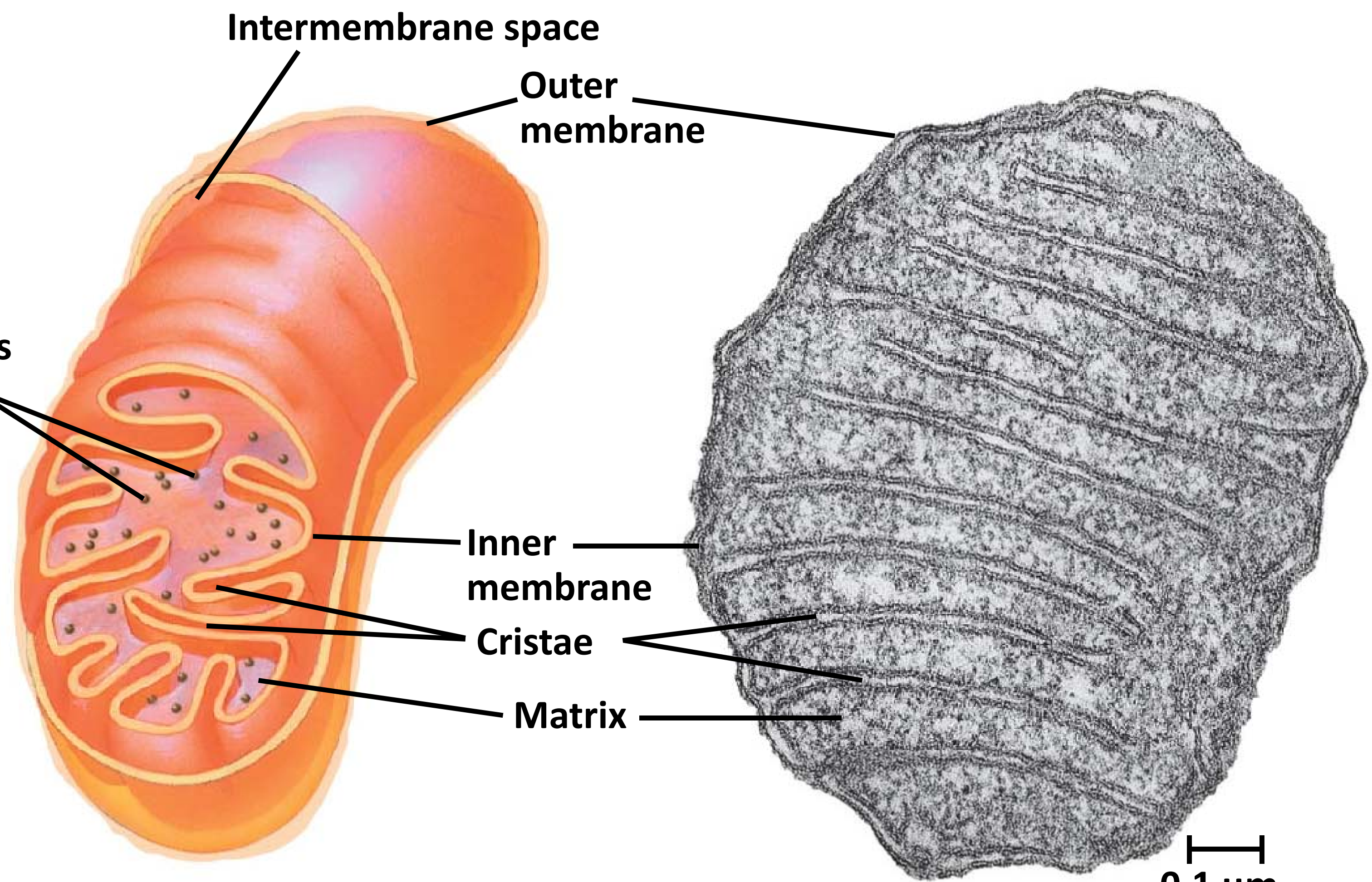


Mitochondria and chloroplasts change energy from one form to another

Mitochondria (mitochondrion in singular) are the sites of **cellular respiration**, a metabolic process that generates ATP by extracting energy from sugars, fats, and other fuels with the help of oxygen. Found in plant and animal cells.

Chloroplasts are the sites of **photosynthesis.** They convert solar energy into chemical energy by absorbing sunlight and using it to drive the synthesis of organic compounds such as sugars from carbon dioxide and water. Found in plants and some algae.

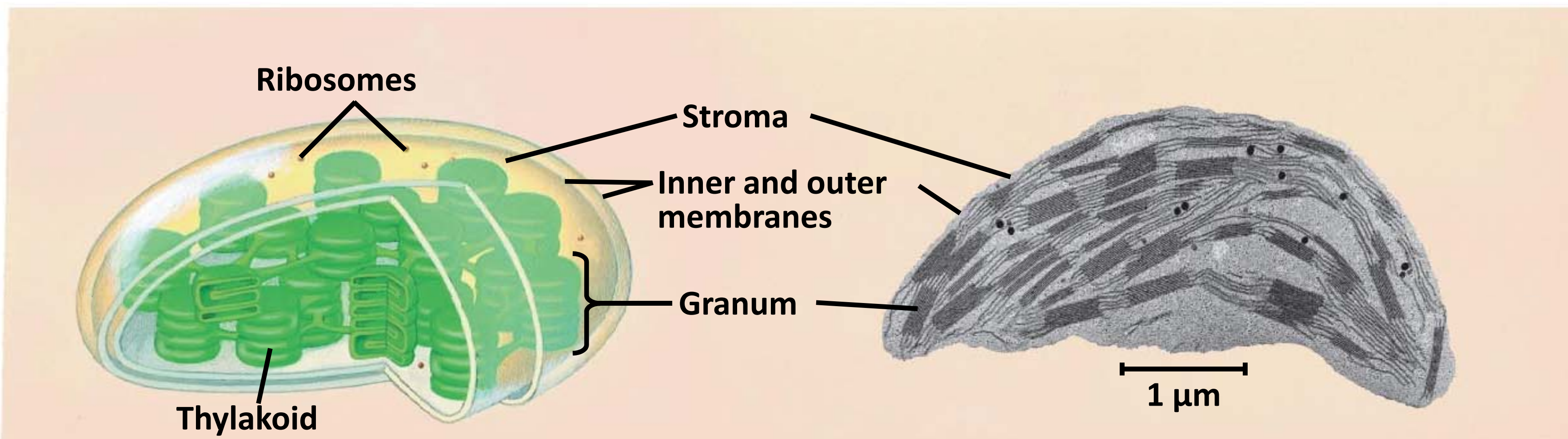
Fig. 6-17



The mitochondrion, site of cellular respiration

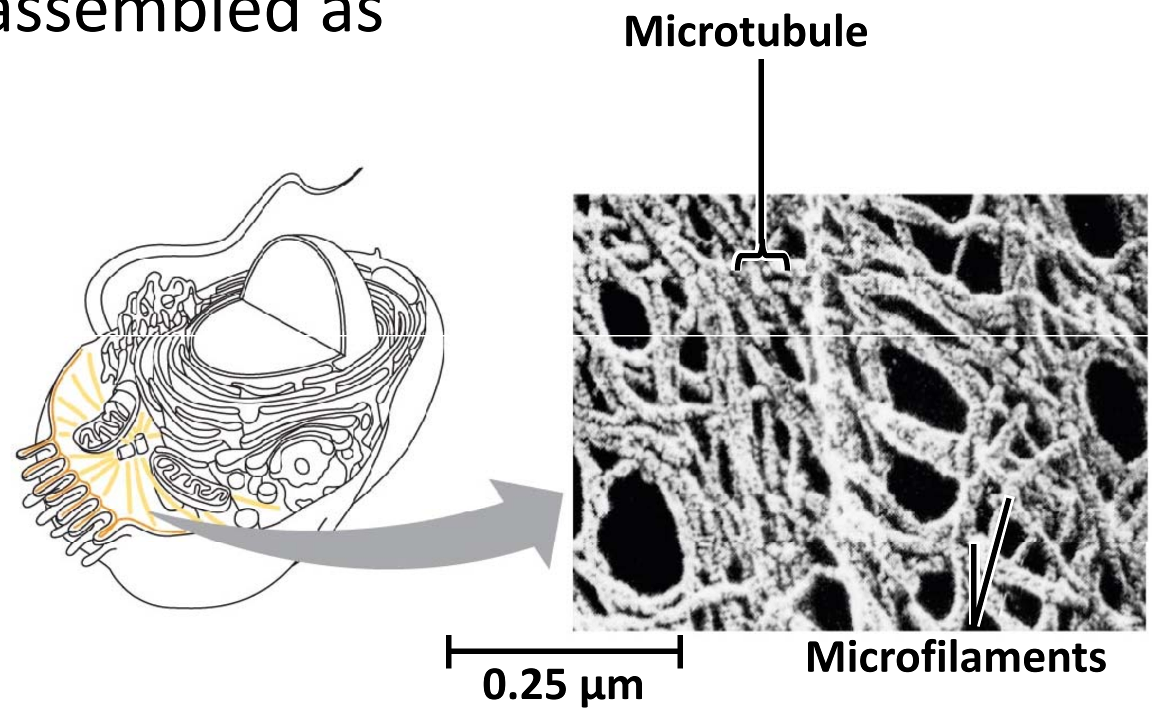
Chloroplasts: Capture of Light Energy

- Chloroplasts contain the green pigment chlorophyll, as well as enzymes and other molecules that function in photosynthesis
- Chloroplasts are found in leaves and other green organs of plants and in algae
- Chloroplast structure includes:
  - **Thylakoids**, membranous sacs, stacked to form a **granum**
  - **Stroma**, the internal fluid



The cytoskeleton is a network of fibers that organizes structures and activities in the cell

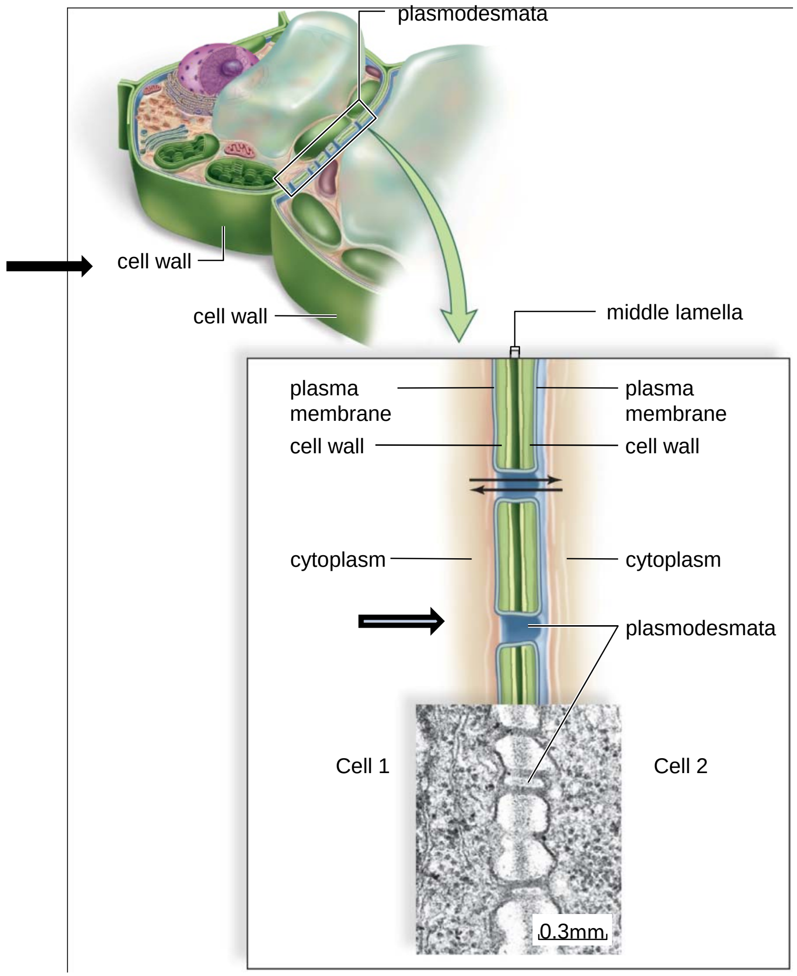
- Maintains cell shape
- Assists in movement of the cell and organelles
- Assembled and disassembled as needed



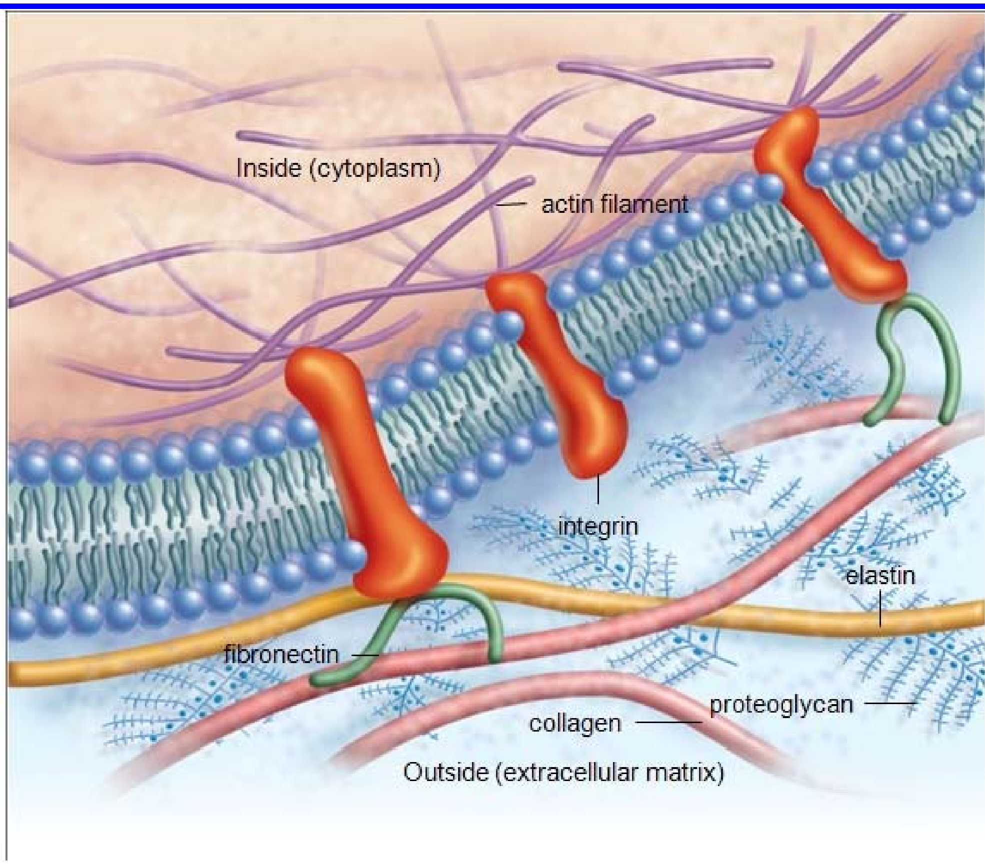
Extracellular structures in Plant Cells

- The **cell wall** is an extracellular structure that distinguishes plant cells from animal cells
- Plant cell walls are made of cellulose fibers embedded in other polysaccharides and protein
- Prokaryotes, fungi, and a few protists also have cell walls (non-cellulose polysacharides: peptidoglycan in bacteria, chitin in fungi).
- The cell wall protects the plant cell, maintains its shape, and prevents excessive uptake or loss of water (turgor pressure)
- **Plasmodesmata** are intercellular junctions in the cell wall of adjacent plant cells

Extracellular Structures in Plants



The Extracellular Matrix (ECM) of Animal Cells



A group of receptor proteins called **integrins** bind to the external ECM and the cytoskeleton inside the cytoplasm

Animal cells lack cell walls but are covered by a meshwork of proteins and polysaccharides close to the membrane **:extracellular matrix (ECM)**

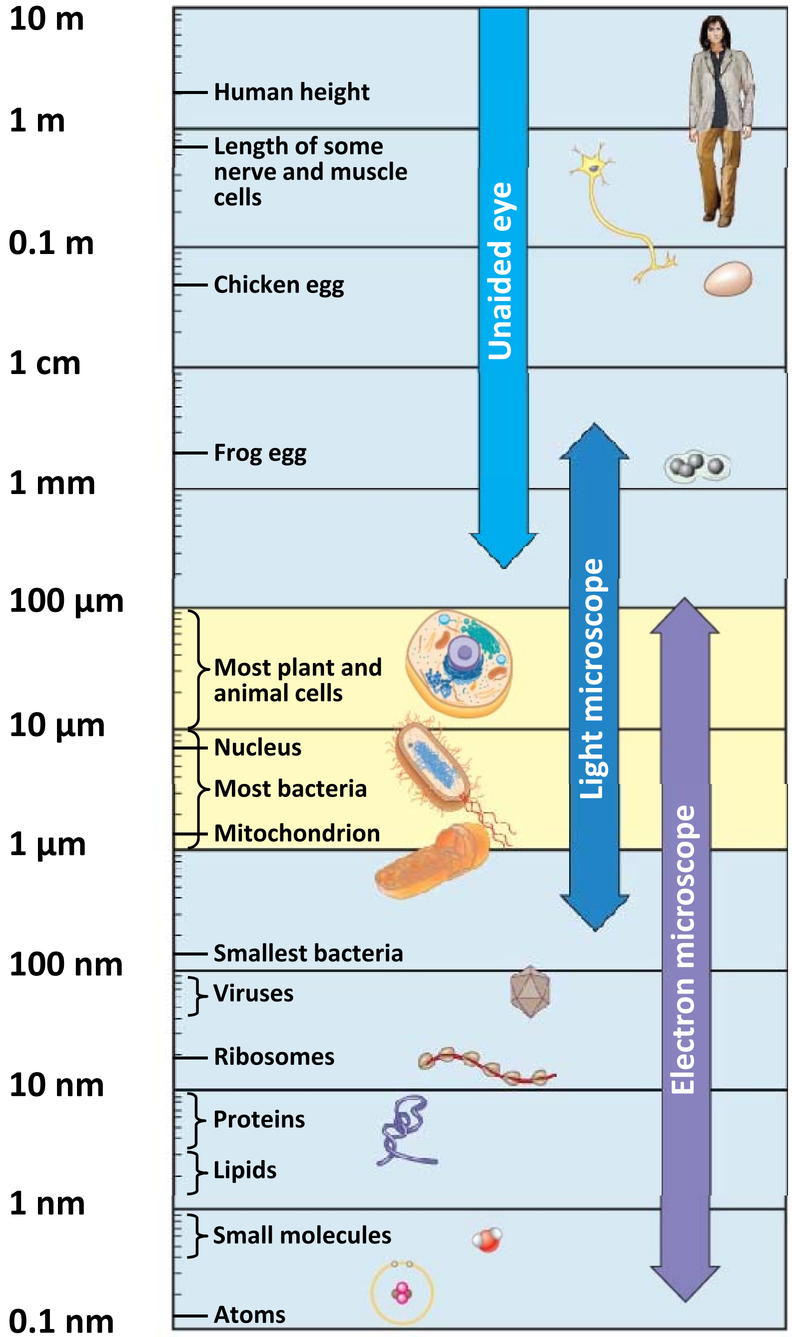
The ECM is made up of **collagen, proteoglycans, fibronectin, elastin**

The ECM composition is different depending on the tissue

Biologists use microscopes and the tools of biochemistry to study cells

- Most cells are between 1 and 100 um in diameter.
- Cells are too small to be seen by the naked eye. They are visible under a microscope

Most cells are between 1-100 um in diameter
Eukaryotic: 10-100
Prokaryotic: 1-5
Mycoplasm : 0.1-1 uM



Details smaller than 0.2 um require an EM

Microscopy

Important parameters determining the quality of the image:

– *Magnification*, the ratio of an object's image size to its real size

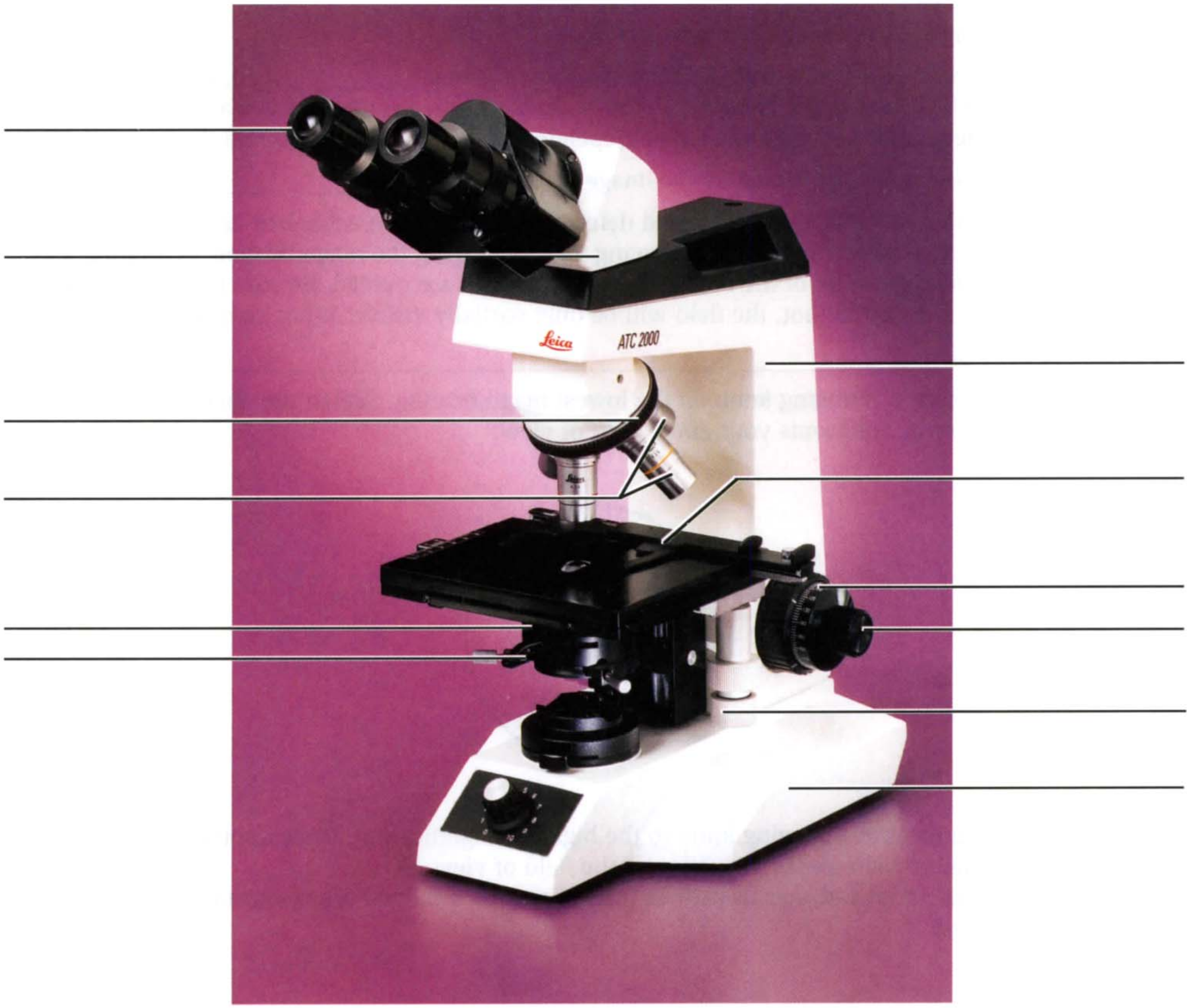
– *Resolution (or resolving power)*, the measure of the clarity of the image, or the minimum distance of two distinguishable points

– *Contrast*, visible differences in parts of the sample

Light microscopes

- In a **light microscope (LM)**, visible light passes through a specimen and then through glass lenses, which magnify the image
- The resolution is about 0.2 um, which is 1000 times greater than that the human eye
- Various techniques enhance contrast and enable cell components to be stained or labeled
- Most subcellular structures, including **organelles** (membrane-enclosed compartments), are too small to be resolved by an LM

Figure 2.7 Compound light microscope.
Compound light microscope with binocular head and mechanical stage.



1. **Eyepieces** (ocular lenses): What is the magnifying power of the ocular lenses on your microscope? ______________________________
2. **Viewing head:** Holds the ocular lenses.
3. **Arm:** Supports upper parts and provides carrying handle.
4. **Nosepiece:** Revolving device that holds objectives.
5. **Objectives** (objective lenses):
   a. **Scanning objective:** This is the shortest of the objective lenses and is used to scan the whole slide. The magnification is stamped on the housing of the lens. It is a number followed by an ×. What is the magnifying power of the scanning objective lens on your microscope? ______
   b. **Low-power objective:** This lens is longer than the scanning objective lens and is used to view objects in greater detail. What is the magnifying power of the low-power objective lens on your microscope? __________
   c. **High-power objective:** If your microscope has three objective lenses, this lens will be the longest. It is used to view an object in even greater detail. What is the magnifying power of the high-power objective lens on your microscope? __________
   d. **Oil immersion objective:** (on microscopes with four objective lenses): Holds a 95× (to 100×) lens and is used in conjunction with immersion oil to view objects with the greatest magnification. Does your microscope have an oil immersion objective?__________If this lens is available, your instructor will discuss its use when the lens is needed.
6. **Stage:** Holds and supports microscope slides. A mechanical stage is a movable stage that aids in the accurate positioning of the slide. Does your microscope have a mechanical stage? ____________
7. **Coarse-adjustment knob:** Knob used to bring object into approximate focus; used only with low-power objective.
8. **Fine-adjustment knob:** Knob used to bring object into final focus.
9. **Condenser:** Lens system below the stage used to focus the beam of light on the object being viewed.
10. **Diaphragm** or **diaphragm control lever:** Controls amount of illumination used to view the object.
11. **Light source:** An attached lamp that directs a beam of light up through the object.
12. **Base:** The flat surface of the microscope that rests on the table.

Fig. 6-3ab

TECHNIQUE

RESULTS

(a) Brightfield (unstained specimen): Human cheek epithelial cell

The image has little contrast in general
It is useful when the cells are naturally pigmented and/or one want to visualize alive cells (for changes in shape for example)

50 µm

(b) Brightfield (stained specimen):

Staining increases the contrast.
The majority of the staining(s) require preservation (fixing) of the cells on the slides (dead cells)

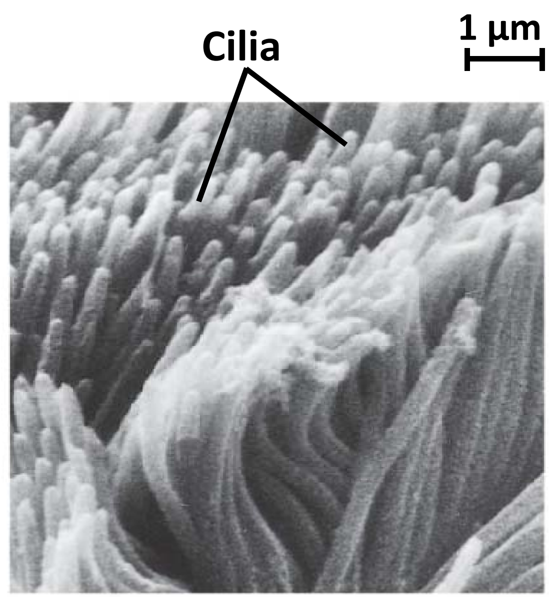
Electronic microscopes

- Two basic types of **electron microscopes (EMs)** are used to study most subcellular structures including organelles
- Resolution is about 2 nm (about 100000 times greater than that of the human eye)
- **Scanning electron microscopes (SEMs)** focus a beam of electrons onto the surface of a specimen, providing images that look 3-D
- **Transmission electron microscopes (TEMs)** focus a beam of electrons through a specimen
  TEMs are used mainly to study the internal structure of cells (section of the specimen)

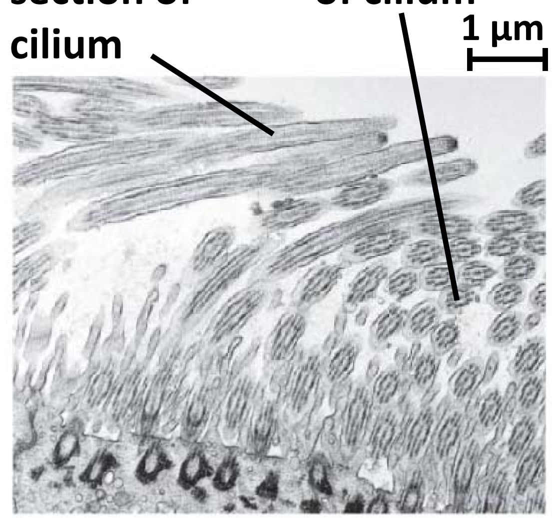
TECHNIQUE

RESULTS

(a) Scanning electron microscopy (SEM)
Shows the surface of a cell from a rabbit trachea covered with motile organelles called cilia



(b) Transmission electron microscopy (TEM)
Shows a thin section of the above specimen (some cilia were cut along their length or cut straight across)



Living organisms are classified within three groups called domains and 6 subgroups called kingdoms:

Domain Archaea	Kingdom Archaea
Domain (Eu)Bacteria	Kingdom Bacteria
Domain Eukarya	Kingdom Plantae Kingdom Animalia Kingdom Fungi Kingdom Protista

TABLE 26.1 Features of the Domains of Life

	DOMAIN		
Feature	**Archaea**	**Bacteria**	**Eukarya**
Amino acid that initiates protein synthesis	Methionine	Formyl-methionine	Methionine
Introns	Present in some genes	Absent	Present
Membrane-bounded organelles	Absent	Absent	Present
Membrane lipid structure	Branched	Unbranched	Unbranched
Nuclear envelope	Absent	Absent	Present
Number of different RNA polymerases	Several	One	Several
Peptidoglycan in cell wall	Absent	Present	Absent
Response to the antibiotics streptomycin and chloramphenicol	Growth not inhibited	Growth inhibited	Growth not inhibited

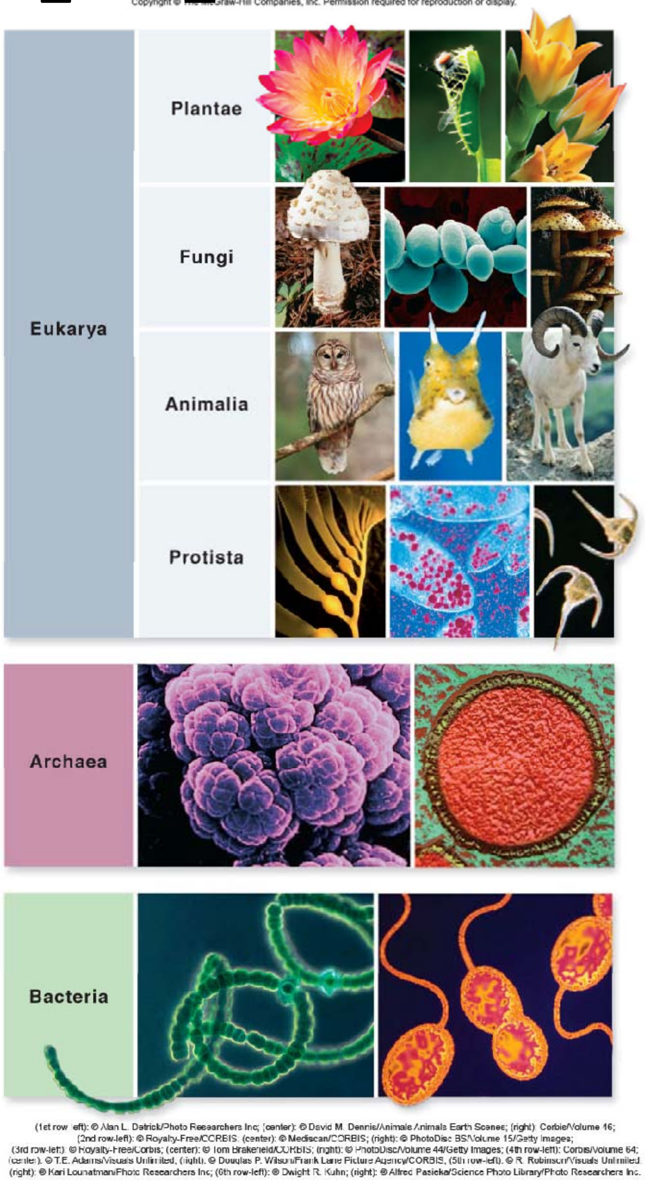
TABLE 26.2 Characteristics of the Six Kingdoms and Three Domains

	 Archaea and Bacteria	 Protista	 Plantae	 Fungi	 Animalia
Cell Type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Nuclear Envelope	Absent	Present	Present	Present	Present
Transcription and Translation	Occur in same compartment	Occur in different compartments	Occur in different compartments	Occur in different compartments	Occur in different compartments
Histone Proteins Associated with DNA	Absent	Present	Present	Present	Present
Cytoskeleton	Absent	Present	Present	Present	Present
Mitochondria	Absent	Present (or absent)	Present	Present	Present
Chloroplasts	None (photosynthetic membranes in some types)	Present (some forms)	Present	Absent	Absent
Cell Wall	Noncellulose (polysaccharide plus amino acids)	Present in some forms, various types	Cellulose and other polysaccharides	Chitin and other noncellulose polysaccharides	Absent
Means of Genetic Recombination, If Present	Conjugation, transduction, transformation	Fertilization and meiosis	Fertilization and meiosis	Fertilization and meiosis	Fertilization and meiosis
Mode of Nutrition	Autotrophic (chemosynthetic, photosynthetic) or heterotrophic	Photosynthetic or heterotrophic, or combination of both	Photosynthetic, chlorophylls *a* and *b*	Absorption	Ingestion
Motility	Bacterial flagella, gliding or nonmotile	9 + 2 cilia and flagella; amoeboid, contractile fibrils	None in most forms; 9 + 2 cilia and flagella in gametes of some forms	Both motile and nonmotile	9 + 2 cilia and flagella, contractile fibrils
Multicellularity	Absent	Absent in most forms	Present in all forms	Present in most forms	Present in all forms
Nervous System	None	Primitive mechanisms for conducting stimuli in some forms	A few have primitive mechanisms for conducting stimuli	None	Present (except sponges), often complex

Life Diversity and Classification

Domains

Kingdoms



Multicellular organisms that have eukaryotic cells with cell walls of cellulose and obtain energy by photosynthesis

Multicellular organisms that have eukaryotic cells with cell walls of chitin and can not do photosynthesis

Multicellular organisms that have eukaryotic cells that do not have cell walls and cannot do photosynthesis

Unicellular or multicellular with eukaryotic cells and very diverse (some can do photosynthesis, some can not, move by different mechanisms)

Unicellular, Prokaryotic, cell wall lacks peptidoglycan, antibiotics do not inhibit their growth

Unicellular, Prokaryotic, cell wall has peptidoglycan, antibiotics streptomycin and chloramphenicol inhibit their growth

Classification Activity:

Indicate the Domain and Kingdom of the following organisms using the “keys” shown.

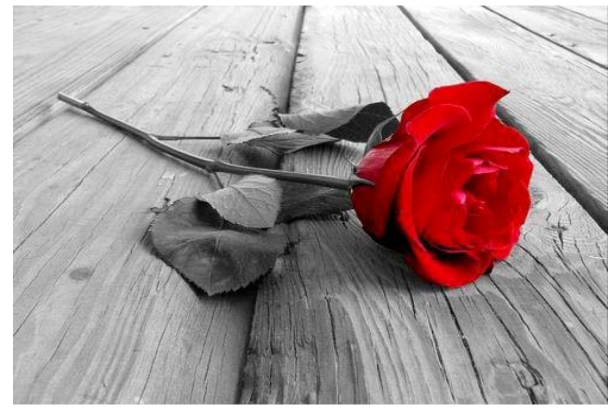
Please note each slide corresponds to the same group of organisms. One of the organisms is not considered a living organism and therefore it can not be classified within any domain or kingdom

Example

Keys:

Nuclear envelope is present

Have cellulose in the cell wall



Answer:

Domain Eukarya, Kingdom Plantae

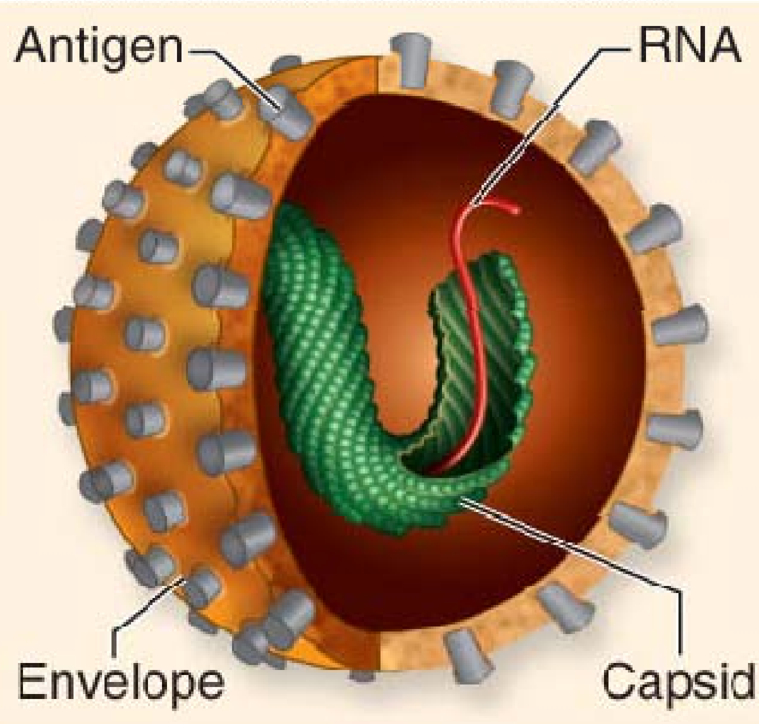
Structure	
Virus	Animal virus (Influenza)
Viral shape	Helical capsid within envelope

Figure 1

Key: It is a virus!!!

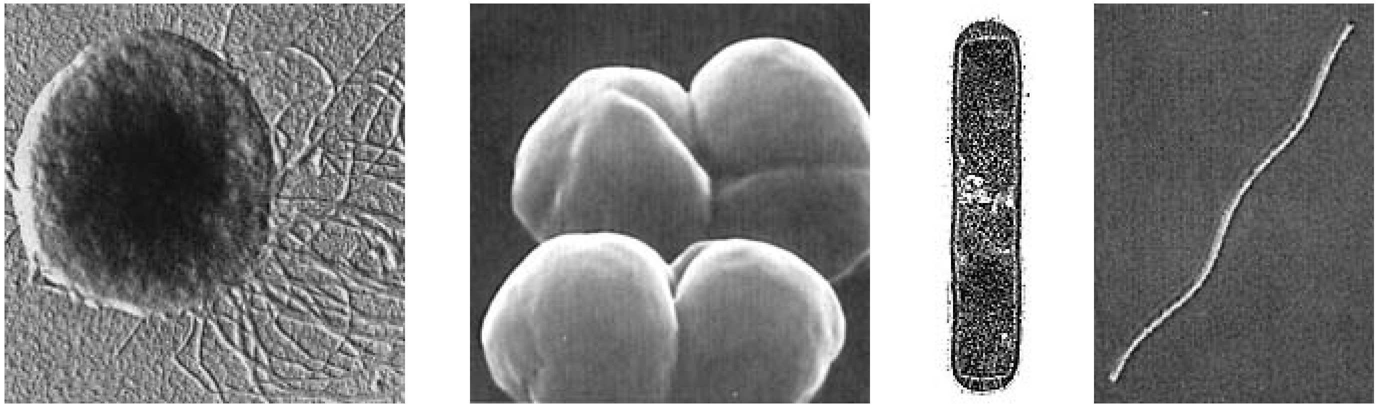


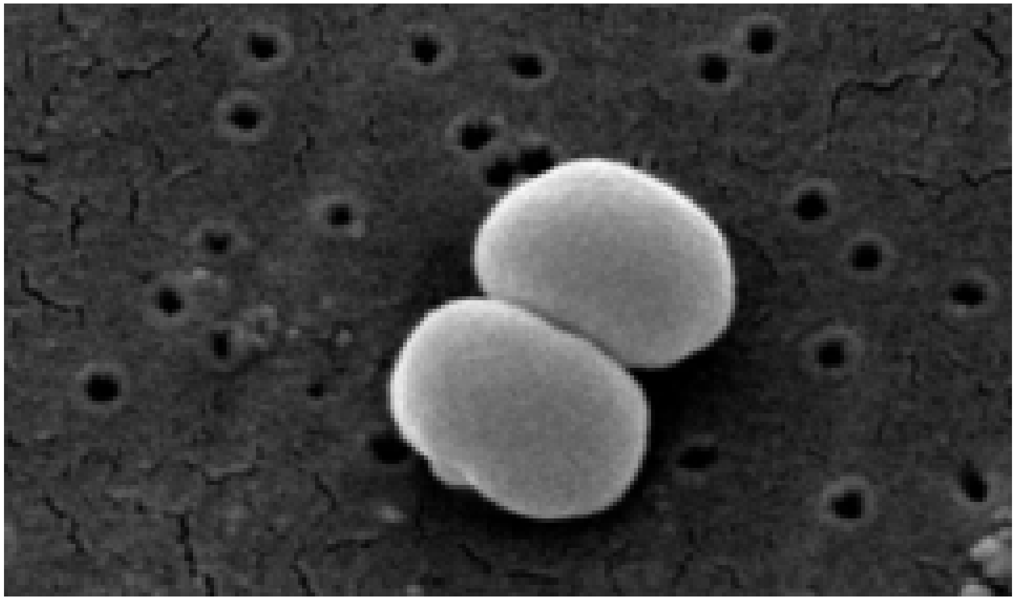
Figure 2. At far left, *Methanococcus janaschii*, a **coccus** form with numerous flagella attached to one side. At left center, *Methanosarcina barkeri*, a lobed coccus form lacking flagella. At right center, *Methanothermus fervidus*, a short **bacillus** form without flagella. At far right, *Methanobacterium thermoautotrophicum*, an elongate bacillus form.

Keys:

Nuclear envelope is absent

Do not Have peptidoglycan in the Cell wall

Their growth is not inhibited in response to the antibiotics streptomicin and chloramphenicol



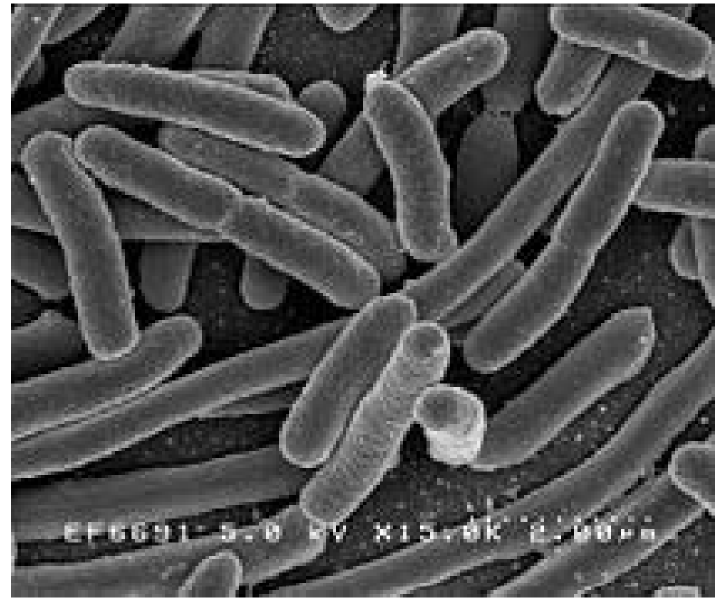


Fig. 3: Left, *Staphylococcus epidermis,* Right*, E. Coli*

Keys:
Nuclear Envelope is absent
Their growth is inhibited in response to the antibiotics streptomycin and chloramphenicol

Fig. 4:

Keys:
Nuclear envelope is present
Have cellulose in the cell wall

Amanita rubrovolvata

Penicillium

Pilobolus crystallinus

Fig. 5:

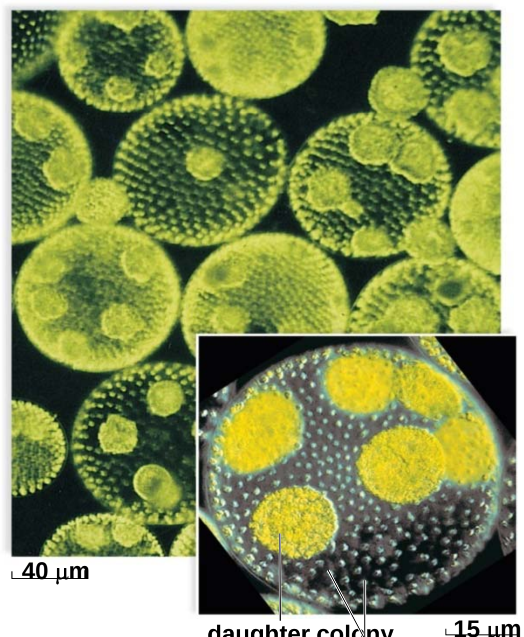
Keys:
Nuclear envelope is present
Have a cell wall with chitin and other non cellulose polysaccharides
Are Heterotrophs

Amoeba

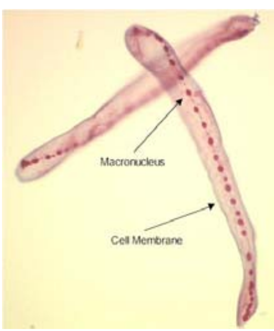
Paramecium

Fig. 6: **Keys:**
Nuclear envelope is present
They are not fungi, plants or animals
Many are unicellular, some are multicellular
They represent all symmetries and exhibit all types of nutrition.

Slime molds



Volvox



Spirostomum

Diatoms

Fig. 7:

Keys:
Nuclear envelope is present
Are heterotrophs (they do not make their own food)
They do not have a cell wall

Origin of Prokaryotes

First Prokaryotic cells emerged around 3.5 BYA (ocean temperatures are thought to be around 120-190 oF)

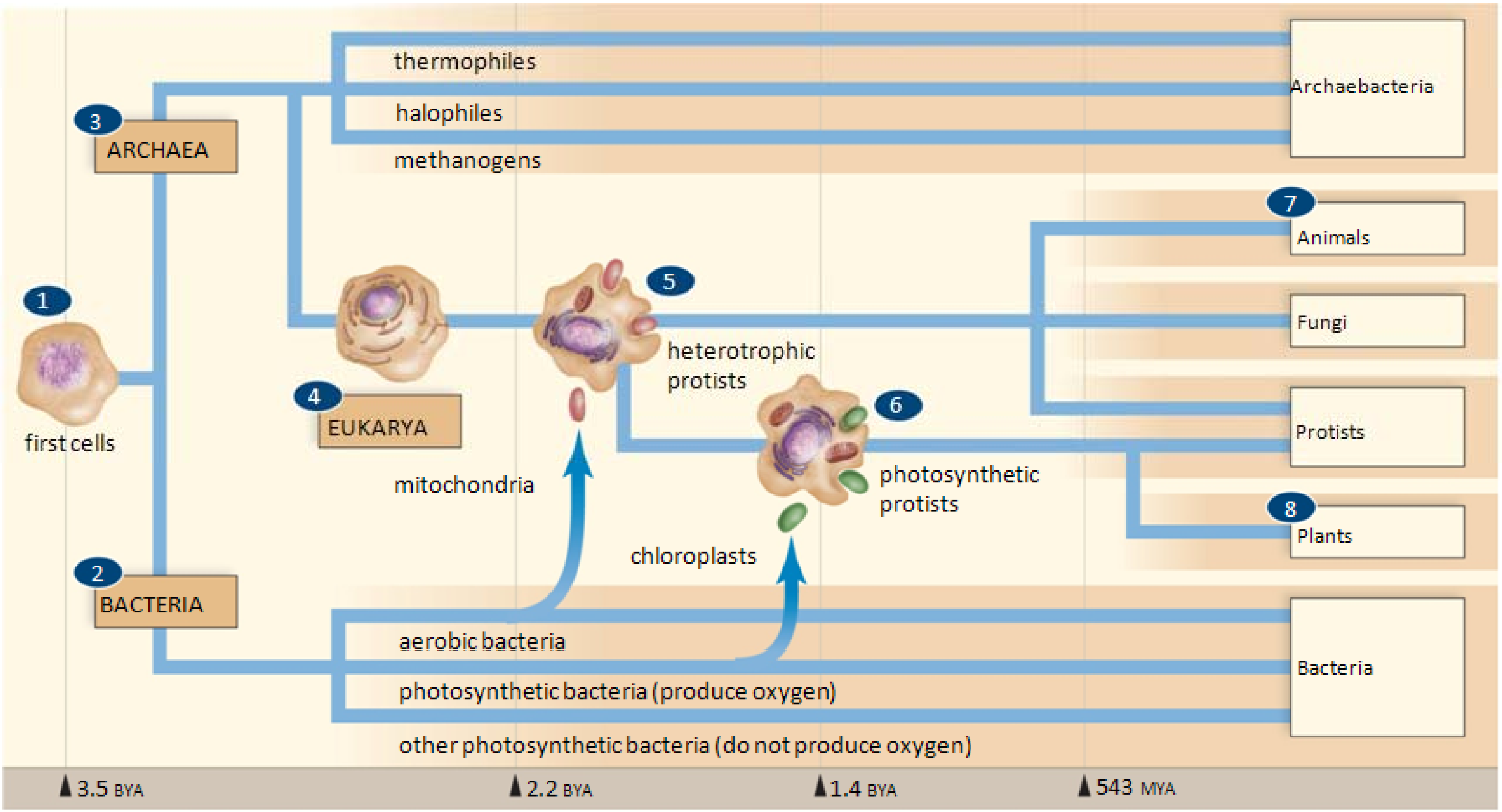
Prokaryotes ruled the Earth for at least one billion years **(did not have nuclear membranes and were very small).**

How did Eukaryotic Cells Arise?

- Eukaryotic cells arose around 2.1 BYA.
- Explained by the Endosymbiotic Theory:

http://highered.mcgraw-hill.com/sites/9834092339/student_view0/chapter4/animation_-_endosymbiosis.html

  - Mitochondria were probably once free-living aerobic prokaryotes.
  - Chloroplasts were probably once free-living photosynthetic prokaryotes.
  - A nucleated cell probably engulfed these prokaryotes that became various organelles.
  - Cilia and flagella may have originated from slender undulating prokaryotes that attached to the host cell.



During the Precambrian time, the first cell or cells (1) give rise to bacteria (2) and archaea (3); the first eukaryotic cell evolves from archaea. Heterotrophic protists (5) arise when eukaryotic cells gain mitochondria by engulfing aerobic bacteria, and photosynthetic protists (6) arise when these cells gain chloroplasts by engulfing photosynthetic bacteria. Animals (and fungi) (7) evolve from heterotrophic protists, and plants (8) evolve from photosynthetic protists. BYA = billion years